2020

MADE EASY

WORKBOOK

Thermodynamics + Refrigeration and Air-conditioning + Heat Transfer

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Section-B Refrigeration and Air-conditioning

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RAC
Description Sheet

Basic Concepts
- Refrigeration Effect
- Heat pump and Refrigeration
- Ideal refrigeration cycle
- Unit of refrigeration

VCRS
- Basic components of VCRS
- DRY compression vs Wet compression
- Basics of volumetric efficiency
- Effect of various parameters on the performance of VCRS
- Flash chamber
- Use of heat exchanger in VCRS
- Cascade refrigeration system

Refrigerants
- Nomenclature of refrigeration
- Propertries of refrigeration
- Azeotropes
- Application of refrigeration

Reversed Brayton Cycle (RBC)
- Basic components of cycle
- COP of reverse Brayton cycle
- Isentropic efficiency

VARS [Vapour jet, Thermoelectric vortex tube refrigeration]
- Basic components
- COP of VARS (derivation required)
- Electrolux refrigeration system
- Concept of vapour jet, thermodelectric and vortex tube **(Only in IES)**

Refrigeration Equipment
- Volumetric efficiency
- Performance parameters
- Condenser and evaporator
- Expansion device
- Heat rejection ratio

Psychrometery/AC
- Various terms
- Development of psychrometeric chart
- Various processes
- Sensible heat factor
- Simultaneous representation of process
- Comfort chart/effective temperature
- Ventilation air

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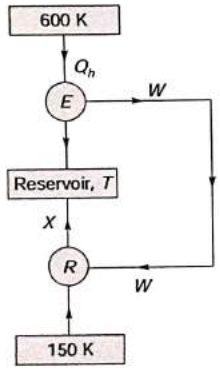
1 Heat Engine, Heat Pump, Refrigerator & Reversed Carnot Cycle

Multiple Choice Questions

Q.1 A domestic refrigerator set at 2°C handles on the average a thermal load of 8000 kJ/day. The ambient temperature is 30°C. The COP of the refrigerator is equal to 0.15 times that of a Carnot refrigerator. The daily electricity consumption (in kWh) is approximately

(a) 1.47 (b) 1.51
(c) 3.28 (d) 2.86

Q.2 In the system shown in figure, the temperature T = 300 K. When is the thermodynamic efficiency η_E of engine E equal to the reciprocal of the COP of R?



(a) When R acts as a heat pump
(b) When R acts as a refrigerator
(c) When R acts both as a heat pump and a refrigerator
(d) When R acts as neither a heat pump nor a refrigerator.

Q.3 Two carnot refrigerators are employed one for ice making and other for comfort cooling

(a) The COP of refrigerator for ice making is higher than that for the other
(b) The COP of refrigerator for ice making is lower than that for the other
(c) The COP of refrigerator for ice making is same as that for the other
(d) The COP of carnot refrigerator will depend on refrigerant used

Q.4 A Carnot refrigerator works with a temperature range of –5°C to 40°C on (i) R–12 (ii) R–717 (iii) Air

(a) COP with R–12 is greater than COP with R–717
(b) COP with R–12 is greater than COP with air
(c) COP with R–12 is equal to COP with R–717
(d) COP with R–717 is greater than COP with air.

Q.5 A refrigerator system operates on the reversed Carnot system cycle. The temperature for the system are:

Higher temperature = 40°C
Lower temperature = 20°C

The capacity of the refrigeration system is 10 TR. What is the heat rejected (in kJ/s) from the system if all the losses are neglected?

(a) 12.5 (b) 37.4
(c) 23.8 (d) None of these

Q.6 A condenser of a refrigeration system rejects heat at rate of 120 kW, while its compressor consumes a power of 30 kW. The coefficient of performance of the system would be

(a) 1/4 (b) 1/3
(c) 3 (d) 4

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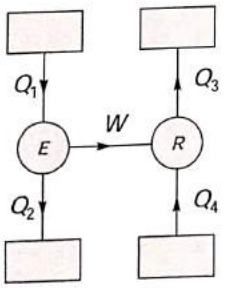
Q.7 The working temperatures in the evaporator and condenser coils of a refrigerator are –30°C and 32°C respectively. If the actual refrigerator has COP of 0.75 of the maximum, the required power input for refrigerating effect of 5 kW is, nearly
(a) 1.7 kW
(b) 2.94 kW
(c) 3.92 kW
(d) 4.0 kW

Q.8 A one ton capacity water cooler cools water steadily from 35°C to 20°C. The specific heat of water is 4.18 kJ/kgK. The water flow rate will be nearly,
(a) 13.33 *l*/hr (b) 33.3 *l*/hr
(c) 200 *l*/hr (d) 250 *l*/hr

Q.9 A carnot refrigerator requires 1.5 kW/ton of refrigeration to maintain a region at a temperature of – 30°C. The COP of the Carnot refrigerator is
(a) 1.42 (b) 2.33
(c) 2.87 (d) 3.26

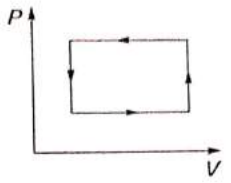
Q.10 A refrigerator based on reversed carnot cycle works in between two such temperatures that the ratio between the low and high temperature is 0.8, if a heat pump is operated between same temperature range, then what would be its COP?
(a) 2 (b) 3
(c) 4 (d) 5

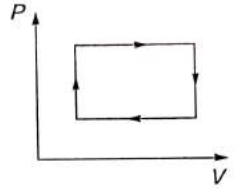
Q.11 In the below figure, E is a heat engine with efficiency of 0.4 and R is a refrigerator. Given that $Q_2 + Q_4 = 3Q_1$ the COP of the refrigerator is

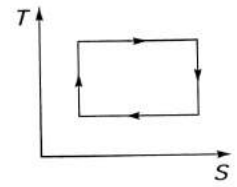


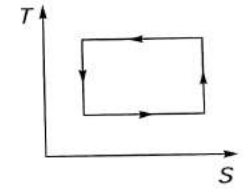
(a) 2.5 (b) 3.0
(c) 6.0 (d) 5.0

Q.12 Which one of the following figure correctly represent Carnot refrigeration cycle?

(a)


(b)


(c)


(d)


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(a) Both *A* and *R* are individually true and *R* is correct explanation of *A*
(b) Both *A* and *R* are individually true but *R* is not correct explanation of *A*
(c) *A* is true but *R* is false
(d) *A* is false but *R* is true

Q.13 **Assertion (A):** Although a heat pump is a refrigerating system, the coefficient of performance differs when it is operating on the heating cycle.
Reason (R): It is the condenser heat that is useful (the desired effect) instead of the refrigerating effect.

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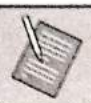
Q.14 **Assertion (A)** : The COP of an air-conditioning plant is lower than that of an ice plant.
Reason (R) : The temperatures required in the ice plant are lower than those required for an air-conditioning plant.

Numerical Data Type Questions

Q.15 In a certain ideal refrigeration cycle, the COP of the refrigerator is 3. The cycle under ideal conditions running as heat engine will have efficiency equals to _____%.

Q.16 A heat pump is used to heat a house in the winter and reversed to cool a house in the summer: the inside temperature of the house is to be maintained at 20°C the heat transfer through the house wall is 7.9 kJ/s and the outside temperature in winter is 5°C. The minimum power required to drive the heat pump is _____ kW.



Conventional Questions

Q.17 A refrigerator storage is supplied with 3600 kg of fish at a temperature of 27°C. The fish has to be cooled to –23°C for preserving it for a long period without deterioration. The cooling takes place in 10 hours. The specific heat of fish is 2.0 kJ/kgK above freezing point of fish and 0.5 kJ/kgK below freezing point, which is –3°C. The latent heat of freezing is 230 kJ/kg. What is the power to drive the plant if the actual COP is half that of ideal COP?

Try Yourself

T1. A refrigerating machine in heat pump mode has a COP of 4. If it is worked in refrigerator mode with a power input of 3 kW. Evaluate the heat extracted from the food kept in the refrigerator.
[Ans. 540 kJ/min]

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2 Vapour Compression Refrigeration System

Multiple Choice Questions

Q.1 In system *A* vapours are superheated by 10°C in the evaporator while is system *B* vapours are superheated by 10°C in a liquid vapour regenerative heat exchanger, other conditions being the same. Then

(a) COP of *A* = COP of *B*

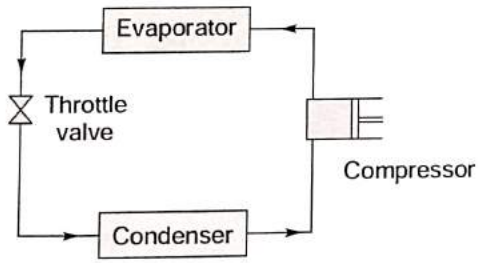
(b) COP of both *A* and *B* > COP of reversed carnot cycle

(c) COP of *A* > COP of *B*

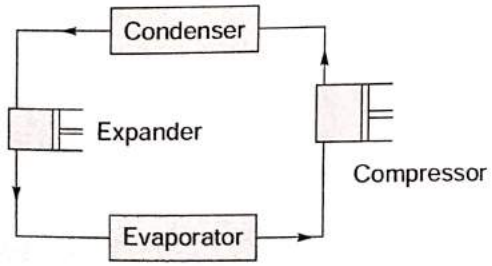
(d) COP of *A* < COP of *B*

Q.2 The schematic diagram of a vapour compression refrigeration system can be represented as

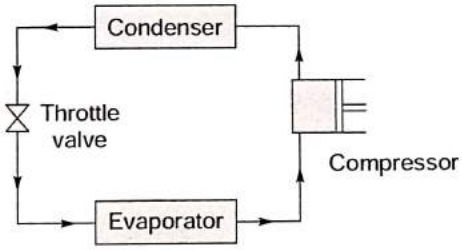
(a)



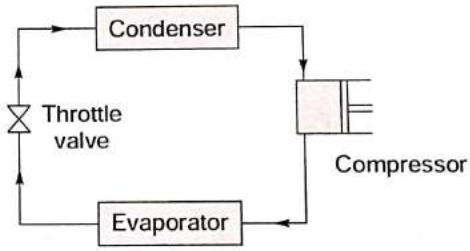
(b)



(c)



(d)



Q.3 Consider the following statements:
Dry compression in reciprocating compressor is preferred because it

1. Prevents valve damage
2. Enables use of thermostatic expansion valve
3. Minimise irreversibilities in the compressor
4. Prevents washing out of the lubricating oil from cylinder walls

Which of these statements are correct?

(a) 1 and 2 (b) 2 and 3

(c) 1 and 4 (d) 3 and 4

Q.4 In a vapour compression refrigeration cycle for making ice, the condensing temperature for higher COP

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(a) Should be near the critical temperature of the refrigerant
(b) Should be above the critical temperature of the refrigerant
(c) Should be much below the critical temperature of the refrigerant
(d) Could be of any value as it does not affect the COP

Q.5 Experimental measurements on a refrigeration system indicate that rate of heat extraction by the evaporator, rate of heat rejection in the condensor and rate of heat rejection by the compressor body to environment are 70 kW, 90 kW and 5 kW respectively. The power input (in kW) required to operate the system is
(a) 15 (b) 20
(c) 25 (d) 75

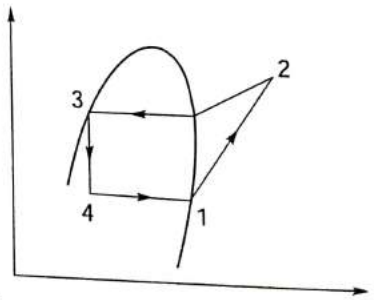
Q.6 Consider the following statements :
In the case of VC machine, if the condensing temperature of the refrigerant is closer to the critical temperature, then there will be
1. Excessive power consumption
2. High compression
3. Large volume flow
Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

Q.7 In VC plant, if certain temperature differences are to be maintained in the evaporator and condenser in order to obtain the necessary heat transfer, then the evaporator saturation temperature must be
(a) Higher than the desired cold-region temperature and the condenser saturation temperature must be lower than available cooling water temperature by sufficient amounts
(b) Lower than the desired cold region temperature and the condenser saturation temperature must be lower than the available cooling water temperature by sufficient amounts
(c) Lower than the desired cold region temperature and the condenser saturation temperature must be higher than the available cooling water temperature by sufficient amounts.
(d) Higher than the desired cold region temperature and the condenser saturation must be higher than the available cooling water temperature by sufficient amounts

Q.8 For a heat pump working on VC cycle, enthalpy values of the working fluid at the end of heat addition process, at the end of compression process, at the end of heat rejection process, and at the end of isenthalpic expansion process are 195 kJ/kg, 210 kJ/kg, 90kJ/kg and 90 kJ/kg respectively. The mass flow rate is 0.5 kg/s. Then the heating capacity of heat pump is,
(a) 7.5 kW (b) 45 kW
(c) 52.5 kW (d) 60 kW

Q.9 The compressor of an ammonia refrigerating machine has a volumetric efficiency of 85% and swept volume of 0.28 m^3/min. Ammonia having a dry specific volume of 0.25 m^3/kg enters the compressor with a dryness fraction of 0.7. The mass flow rate of ammonia through the machine is
(a) 1.28 kg/min (b) 1.36 kg/min
(c) 1.42 kg/min (d) 1.54 kg/min
[ESE : 2018]

Q.10 The vapour compression refrigeration cycle is represented as shown in figure below, with state 1 being the exit of the evaporator. The coordinate system used in this figure is



(a) *P–h* (b) *T–s*
(c) *P–s* (d) *T–h*

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(b) Both *A* and *R* are individually true but *R* is not correct explanation of *A*
(c) *A* is true but *R* is false
(d) *A* is false but *R* is true

Q.11 **Assertion (A):** In a vapour compression refrigeration system, the condenser pressure should be kept as low as possible.
Reason (R): Increase in condenser pressure reduces refrigeration and increase work of compression.

Q.12 **Assertion (A):** In V-C system throttle valve is used and not expansion cylinder.
Reason (R): Throttling is a constant enthalpy process.

Q.13 **Assertion (A) :** Sub-cooling of a refrigerant liquid increases the coefficient of performance of a refrigeration cycle.
Reason (R) : Sub-cooling reduces the work requirement of the refrigeration cycle.

[ESE : 2017]

Numerical Data Type Questions

Q.14 Subcooling heat exchanger is used in a refrigeration cycle. The enthalpies at condenser outlet and evaporator outlet are 78 and 182 kJ/kg respectively. The enthalpy at outlet of isentropic compressor is 230 kJ/kg and enthalpy of subcooled liquid is 68 kJ/kg. The COP of the cycle is _____.

Q.15 In cascade refrigeration system, $(COP)_1 = 2.3$ and $(COP)_2 = 1.6$, the overall efficiency of cascade refrigeration system is _____.

Q.16 Refrigerant vapor enters into the compressor of a standard vapor compression cycle at – 10°C (h = 402 kJ/kg) and leaves the compression at 50°C(h = 432 kJ/kg). It leaves the condenser at 30°C (h = 237 kJ/kg). The COP of the cycle is _____.

[GATE : 2015]

Conventional Questions

Q.17 In a 5 kW loading capacity refrigeration system operating on simple VCRS cycle. The refrigerant enters the evaporator with an enthalpy of 75 kJ/kg, leaves with an enthalpy of 183 kJ/kg. The enthalpy at the discharge of compressor is 210 kJ/kg. Calculate the
(i) COP
(ii) Power consumption in kW
(iii) Rate of heat transfer across condenser in kW

Q.18 A refrigerant based on ideal VCRS operates between a temperature limit of –20 and +40 °C. The refrigerant enters the condenser as saturated vapour and leaves the condenser as saturated liquid. The enthalpy and entropy values of the refrigerant are given below in the table.

t(°C)	h_f(kJ/kg)	h_g(kJ/kg)	s_f(kJ/kg)	s_g(kJ/kgK)
–20	20	180	0.07	0.7366
+40	80	200	0.03	0.67

(i) Find the COP
(ii) If the mass flow rate 0.025 kg/s then find the refrigeration effect in kW.

Q.19 A VCRS system using R-12 is employed to produce 8640 kg of ice/day. The condensing and evaporator of refrigerant are 48°C and –20°C. Saturated liquid leaves the condenser and saturated vapour leaves the evaporator. The compression is isentropic and water at 35°C is used to form ice and the temperature of the ice

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should be – 8°C. Heat flows into the brine tank from surrounding which is 10% of total heat removed from water to from ice. Determine of total power required to drive the compressor in kW.

Assume specific heat of ice 2.26 kJ/kgK, latent heat of ice is 334.72 kJ/kg and specific heat of vapour refrigerant (c_p) = 0.82 kJ/kgK.

t(°C)	P(bar)	h_f(kJ/kg)	h_g(kJ/kg)	s_f	s_g
48	11.64	82.83	205.83	0.2973	0.6802
–20	1.51	17.82	178.74	0.0731	0.7087

Q.20 A food storage requires a refrigeration capacity of 15 TR. It works between –10° and 30°C. The temperature of refrigerant superheated as gas in evaporator is –5°C and temperature of refrigerant subcooled as liquid in the condenser is 25°C. No. of cylinders are equal to 2, stroke is 1.5 times the bore and speed is 960 rpm. Determine

(I) (a) RE/kg
(b) Mass flow rate of refrigerant is kg/min
(c) Theoretical piston displacement
(d) COP
(e) Bore and stroke of the compressor

(II) If the clearance volume is 3% of stroke volume then
(a) Determine volumetric η
(b) Bore and stroke of the compressor

The specific heat of liquid is taken as 0.963 kJ/kgK and specific heat of vapour is 0.615 kJ/kgK.

t(°C)	P(bar)	h_f(kJ/kg)	h_g(kJ/kg)	s_f (kJ/kg)	s_g (kJ/kg)	v(m³/kg)
–10	2.1928	190.72	347.96	0.96561	1.5632	0.07702
30	7.4458	229.11	364.96	1.0999	1.5481	0.02372

Q.21 A food storage requires a refrigeration capacity of 50 kW. It works between a condenser temperature of 35°C and evaporator temperature of –10°C. The refrigerant is NH_3. It is subcooled by 5°C in a HE before entering the expansion valve and simultaneously the refrigerant is superheated after leaving the evaporator. Assume a single cylinder operating at 1000 rpm. With stroke is 1.2 times the bore. Determine (i) The power required, (ii) Cylinder dimensions

t°C	P(bar)	h		s		v		Sp.heat	
		h_f	h_g	s_f	s_g	v_f	v_g	Liq.	Vapour
–10	2.9157	154.056	1450.22	0.82965	5.755	—	0.41749	–	2.492
35	13.522	366.07	1488.57	1.56605	5.2086	1.7023	0.09563	4.556	2.903

Q.22 A refrigerant operating on a simple VCRS cycle having a COP of 6.5. The enthalpy of saturated liquid and saturated vapour refrigerant at the operating condenser temperature of 35°C are 69.55 kJ/kg and 201.50 kJ/kg respectively. The saturated refrigerant vapour leaving the evaporator having the enthalpy of 187.53 kJ/kg. The specific heat of vapour refrigerant is 0.6155 kJ/kgK. Find the compressor discharge temperature.

Try Yourself

T1. The temperature limits of an ammonia refrigerating system are 25°C and –10°C. If the gas is dry saturated at the end of compression, find the coefficient of performance of cycle assuming no undercooling of the liquid ammonia. [Use the following table for properties of ammonia]

Temperature (°C)	Enthalpy (kJ/kg)		Entropy (kJ/kgK)
	Liquid	Vapour	Liquid
25	298.9	1465.84	1.1242
–10	135.37	1433.05	0.5443

[Ans 6.8]

T2. In a simple VCRS cycle following are the properties of refrigerant at various points.

	h(kJ/kg)	v(m³/kg)
Comp. inlet	183.2	0.0767
Comp. discharge	222.6	0.0614
Condenses exit	84.9	0.00083

The piston displacement volume is 1.5 litre and speed is 1600 rpm having 80% volumetric efficiency. Find the

(i) RE in kW, (ii) Power in kW

[Ans. (i) RE = 41.012 kW, (ii) 16.44 kW]

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T3. A building requires a 2-tonne heat pump for maintaining the interior space at 27°C when the outside temperature is 5°C. The heat pump operates on the normal vapour compression cycle and uses R-134*a* as the working fluid. The heat pump operating conditions require an evaporator pressure of 240 kPa and a condenser pressure of 1600 kPa while the compressor has an isentropic efficiency of 85%.

P (kPa)	T_{sat} (°C)	h_f (kJ/kg)	h_g (kJ/kg)	s_g (kJ/kgK)
240	–5.37	43	244	0.9222
1600	59.92	134	275	0.8982

For R-134a
at P = 1600 kPa Superheated state
h = 285 kJ/kg
s = 0.9222 kJ/kgK
Find the COP of heat pump.

[Ans. 3.2821]

T4. An ammonia refrigerating machine fitted with an expansion valve works between the temperature limits of –10°C and 30°C. The vapour is 95% dry at the end of isentropic compression and the fluid leaving the condenser as saturated liquid is at 30°C. Ammonia has the following properties:

Temp. (°C)	Liquid heat (h_f) kJ/kg	Latan heat (h_{fg}) kJ/kg	Liquid entropy (s_f) kJ/kgK	Total entropy of dry saturated vapour (kJ/kgK)
30	323.08	1145.80	1.2037	4.9842
–10	135.37	1297.68	0.5443	5.4770

What will be the COP of cycle.

[Ans. 5.8]

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3 Vapour Absorption Refrigeration System

Multiple Choice Questions

Q.1 Waste heat can be effectively used in which one of the following refrigeration systems?
(a) Vapour compression cycle
(b) Air refrigeration cycle
(c) Vapour absorption cycle
(d) Vortex refrigeration system

Q.2 The refrigerant used for absorption refrigerators working from solar collectors is a mixture of water and
(a) CO_2 (b) SO_2
(c) Li–Br (d) R–12

Q.3 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Generator B. Analyser
C. Rectifier D. Receiver

List-II
1. Dehydration
2. Removal of vapour from strong aqua-ammonia solution
3. Producing dry ammonia vapour by removing traces of water particles completely
4. Storage of high pressure liquid ammonia
5. Formation of liquid ammonia from high pressure vapours

Codes:

	A	B	C	D
(a)	3	1	2	5
(b)	5	3	4	2
(c)	1	3	2	5
(d)	2	1	3	4

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Q.4 Hydrogen is essential in an Electrolux refrigeration system, because
(a) it acts as a catalyst in the evaporator
(b) the reaction between hydrogen and ammonia is endothermic in evaporator and exothermic in absorber
(c) the cooled hydrogen leaving the heat exchange cools the refrigerant entering the evaporator
(d) it helps in maintaining a low partial pressure for evaporating ammonia

Q.5 Consider the following statements in respect of absorption refrigeration and vapour compression refrigeration system
1. The former runs on low grade energy.
2. The pumping work in the former is negligible since specific volume of liquid solution is small.
3. The latter user an absorber while former uses a generator.
4. The liquid pump alone replaces compressor of the latter.

Which of these statements are correct?
(a) 1 and 2
(b) 1 and 3
(c) 1 and 4
(d) 2 and 4

Q.6 In a vapour absorption refrigeration, heat is rejected in
(a) condenser only
(b) generator only
(c) absorber only
(d) condenser and absorber

Q.7 In a vapour absorption refrigeration system, if Q_E is the refrigeration produced, Q_G is the heat added in the generator, W_P is pump work, and Q_C and Q_A are the heat rejected in the condenser and absorber respectively, then COP of the system is

(a) $\frac{Q_E}{Q_C + Q_A}$

(b) $\frac{Q_E}{Q_G + W_P}$

(c) $\frac{Q_E - Q_G}{Q_G + W_P}$

(d) $\frac{Q_E - W_P}{Q_C + Q_A}$

Q.8 An Electrolux refrigerator uses
(a) one pump
(b) two pumps
(c) no pump
(d) three pumps

Q.9 For the same condenser and evaporator temperatures, the COP of absorption refrigeration system is less than that of vapour compression refrigeration system, since in the absorption refrigeration system
(a) liquid pump is used for compression
(b) a refrigerant as well as solvent is used
(c) absorber requires heat rejection
(d) low grade energy is used to run the system

Q.10 Absorbent in a vapour absorption refrigeration system separates from the refrigerant only when it
(a) is sufficiently heated
(b) is sprayed on cooling water
(c) is cooled
(d) reacts with refrigerant

Q.11 Consider the following statements in respect of a vapour-absorption refrigeration cycle:
1. The absorption refrigeration cycle is generally used when waste heat is available from an existing source or when free energy like solar energy is to be used.
2. There are no moving parts in the absorption refrigeration plant except a small liquid pump.
3. The value of the coefficient of performance is nearly the same in both vapour-absorption and vapour-compression refrigeration plants.

Which of the above statements are correct?
(a) 1, 2 and 3
(b) 1 and 2 only
(c) 1 and 3 only
(d) 2 and 3 only

[ESE : 2017]

Q.12 **Assertion (A) :** In vapour-absorption system, larger the value of specific solution circulation, more the pump work.

Reason (R) : Higher solution circulation rates of poor as well as rich solutions need larger pressure drops in the system.
(a) Both *A* and *R* are true and *R* is the correct explanation of *A*
(b) Both *A* and *R* are true but *R* is NOT the correct explanation of *A*
(c) *A* is true but *R* is false
(d) *A* is false but *R* is true

[ESE : 2017]

Numerical Data Type Questions

Q.13 Maximum possible COP of a solar absorption refrigeration system with generator temperature of 360 K, absorber temperature of 300 K, condenser temperature of 300 K and evaporator temperature of 270 K is _____.

Q.14 In a vapour absorption refrigeration system the refrigeration temperature is –15°C. The generator is operated by solar heat where the temperature reached is 110°C. The temperature of surrounding where heat rejected is 55°C. The maximum *COP* of the system is _____.

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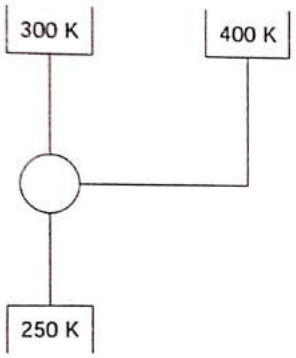
Conventional Questions

Q.15 A vapour absorption refrigeration system is a heat pump with three thermal reservoirs as shown in figure. A refrigeration effect of 100 W is required at 250 K when the heat source available is at 400 K. Heat rejection occurs 300 K. Evaluate the minimum value of heat required.



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Try Yourself

T1. A vapour absorption refrigeration system works with generator, ambient and evaporator temperature as 360 K, 310 K and 260 K respectively. If the evaporator temperature falls to 250 K. What should be the generator temperature in order to operate the system with same COP?

[Ans. 374.9 K]

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4 Refrigerants

Multiple Choice Questions

Q.1 Match **List-I** (Refrigerant) with **List-II** (Principal Application) and select the correct answer using the codes given below the lists:

List-I

A. Air
B. Ammonia
C. Carbon dioxide
D. Refrigerant-11

List-II

1. Direct contact freezing of food
2. Centrifugal compressor system
3. Large industrial temperature installation
4. Automotive air conditioners
5. Aircraft refrigeration

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	5	3	1	2
(c)	2	4	3	5
(d)	5	3	2	1

Q.2 In milk chilling plants, the usual secondary refrigerant is
(a) Ammonia solution
(b) Sodium silicate
(c) Glycol
(d) Brine

Q.3 The desirable combination of properties for a refrigerant include
(a) high specific heat and low specific volume
(b) high heat transfer coefficient and low latent heat
(c) high thermal conductivity and low freezing point
(d) High specific heat and high boiling point

Q.4 A good refrigerant should have
(a) large latent heat of vaporisation and low operating pressures
(b) small latent heat of vaporisation and high operating pressures
(c) large latent heat of vaporisation and large operating pressures
(d) small latent heat of vaporisation and low operating pressures

Q.5 Consider the following statements:
1. Azeotropes are the mixture of refrigerants and behave like pure substances.
2. Isomer refrigerants are compounds with the same chemical formula but have different molecular structures.
3. The formula $n + p + q = 2m$ is used for unsaturated chlorofluoro carbon compounds (m, n, p and q are the number of atoms of carbon, hydrogen, fluorine and chlorine respectively).

Which of these statements are correct?
(a) 1 and 3 (b) 2 and 3
(c) 1 and 2 (d) 1, 2 and 3

Q.6 Consider the following statements regarding refrigerants:
1. Refrigerant NH_3 is used in reciprocating compressors.
2. Refrigerant CO_2 is used in reciprocating compressors.
3. Refrigerant R-11 is used in reciprocating compressors.

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Which of these statement are correct?
(a) 1 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1, 2 and 3

Q.7 Match **List-I** (Refrigerant) with **List-II** (Chemical formula) and select the correct answer using the codes given below the lists:

List-I	List-II
A. R-12	1. CCl_2FCClF_2
B. R-22	2. CHF_2Cl
C. R-717	3. NH_3
D. R-113	4. CCl_2F_2

Codes:

	A	B	C	D
(a)	3	2	4	1
(b)	4	2	3	1
(c)	3	1	4	2
(d)	4	1	3	2

Q.8 Ozone depletion by CFCs occurs by breakdown of
(a) chlorine atoms from refrigerant by *UV* radiation and reaction with ozone in troposphere
(b) fluorine atoms from refrigerant by *UV* radiation and reaction with ozone in troposphere
(c) chlorine atoms from refrigerant by *UV* radiation and reaction with ozone in stratosphere
(d) fluorine atoms from refrigerant by *UV* radiation and reaction with ozone in stratosphere

Q.9 Environment friendly refrigerant R-134*a* is used in new generation domestic refrigerators. Its chemical formula is
(a) $CHClF_2$ (b) $C_2Cl_3F_3$
(c) $C_2Cl_2F_4$ (d) $C_2H_2F_4$

Q.10 In case of leakage of Freon refrigerant, the colour of the flame of halide torch will change to
(a) yellow (b) green
(c) red (d) pink

Q.11 Which one of the following refrigerants has the highest critical temperature?
(a) H_2O (b) CO_2
(c) R-12 (d) NH_3

Q.12 The significant advantage of using ammonia as a refrigerant is its
(a) characteristic odour
(b) high latent heat
(c) solubility in water
(d) inflammability

Q.13 The pipes and fittings in an ammonia refrigeration system should be made of
(a) cast steel or wrought iron
(b) aluminium
(c) naval brass
(d) copper

Q.14 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Sulphur candle test
B. Halide torch test
C. Soap and water test
D. Ammonia swab test

List-II
1. Propane
2. Ammonia
3. Halocarbon refrigerants
4. Sulphur dioxide

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	4	1	3	2
(c)	2	1	3	4
(d)	4	3	1	2

Q.15 Where is an oil separator in vapour compression refrigeration system installed?
(a) Between compressor and condenser
(b) Between expansion valve and receiver tank
(c) Inside compressor machinery
(d) Out side the expansion valve

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Q.16 The use of Refrigerant *R*–22 for temperature below –30°C is not recommended due to its
(a) good miscibility with lubricating oil
(b) poor miscibility with lubricating oil
(c) low evaporating temperature
(d) high compressor discharge temperature
[1993 : 2 Marks]

Q.17 **Assertion (A):** Refrigerants R-11 and R-12 have a greater impact on ozone depletion than R-22.
Reason (R): R-22 has a larger number of chlorine atoms.
(a) Both *A* and *R* are true and *R* is the correct explanation of *A*
(b) Both *A* and *R* are true but *R* is NOT the correct explanation of *A*
(c) *A* is true but *R* is false
(d) *A* is false but *R* is true

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Numerical Data Type Questions

Q.18 The power (kW) required per ton of refrigeration is *N*/COP, where COP is the coefficient of performance, then *N* is equal to _____.

Try Yourself

T1. List out the azeotropes from the following refrigerants
1. R-134a
2. R-22
3. R-11
4. R-502
[Ans. R-502]

■■■■

5 Refrigeration Equipment and Gas Refrigeration

Multiple Choice Questions

Q.1 Match List-I (Refrigeration Equipment) with List-II (Characteristic) and select the correct answer using the codes given below the lists:

List-I

A. Hermetically sealed compressor
B. Semi-hermetically sealed compressor
C. Open type compressor
D. Expansion device

List-II

1. Capillary tube
2. Both compressor and motor enclosed in a shell or casing
3. Both compressor and motor enclosed in a shell or casing with a removable cylinder cover
4. Driving motor is not enclosed in a shell or casing and connected to the shaft driving the compressor

Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	2	3	4	1
(c`	1	3	4	2
(d)	2	4	3	1

Q.2 In a domestic refrigerator periodic defrosting is required because frosting
(a) causes corrosion of materials
(b) reduces heat extraction
(c) overcools food stuff
(d) partially blocks refrigerant flow

[ESE : 2004]

Q.3 When a refrigerator system is started from ambient conditions, the evaporator temperature decreases from ambient temperature to design value. This period is known as pull down period. The power requirement of compressor during pull down
(a) decreases continuously
(b) increases continuously
(c) remain constant
(d) increases and then decreases

Q.4 Which one of the following is responsible for the operation of a thermostatic expansion valve?
(a) Pressure changes in evaporator
(b) Temperature changes in evaporator
(c) Degree of superheat in evaporator
(d) Degree of sub cooling in evaporator

Q.5 In the window air conditioner, the expansion device used is
(a) capillary tube
(b) thermostatic expansion valve
(c) automatic expansion valve
(d) float valve

Q.6 The pressure in a capillary tube decreases due to
1. frictional resistance offered by the tube wall
2. acceleration of refrigerant in the tube
3. heat transfer from tube

Which of these statements is/are correct?:
(a) 1 only
(b) 1 and 2
(c) 1, 2 and 3
(d) 3 only

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Q.7 The presence of air in a condenser
(a) increases the pressure in the condenser and decreases the condensing coefficient
(b) decreases the pressure in the condenser but increases the condensing coefficient
(c) increases the pressure in the condenser as well as the condensing coefficient
(d) decreases the pressure in the condenser as well as the condensing coefficient

Q.8 A rotary compressor is used when a refrigerating system has to handle a refrigerant with
(a) low specific volume and high pressure difference
(b) low specific volume and low pressure difference
(c) large specific volume and high pressure difference
(d) large specific volume and low pressure difference

Q.9 Use of hermetically sealed compressor in a vapour compression refrigeration system results in
(a) decrease in energy consumption
(b) increase in energy consumption
(c) increase in COP
(d) increase in pressure ratio

Q.10 The throttling device used in the domestic refrigerator is
(a) capillary tube
(b) thermostatic expansion value
(c) automatic expansion value
(d) none of these

Q.11 In aircraft, air refrigeration cycle is used because of
(a) low weight per tonne of refrigeration
(b) high heat transfer rate
(c) lower temperature at high attitudes
(d) higher coefficient of performance

Q.12 Consider the following statements :
The presence of air inside condensers
1. remains as a non-condensable gas
2. reduces the condensing coefficient
3. tends to cling to the surface
4. introduces large thermal resistance
Which of the above statements are correct?
(a) 1, 2, 3 and 4 (b) 1, 2 and 3 only
(c) 3 and 4 only (d) 1, 2 and 4 only
[ESE : 2017]

Q.13 In a Bell Coleman cycle refrigeration plant, compression and expansion of air are isentropic. If the temperature of air entering and leaving the expander are 300 K and 180 K respectively, what is the COP of the plant?
(a) 1.5 (b) 2.0
(c) 2.5 (d) 3.0

Q.14 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I
A. Bell Coleman refrigeration
B. Reversed Carnot cycle
C. Milk chilling plant
D. Superheating in refrigeration cycle

List-II
1. Expansion cylinder
2. Heat pump
3. Decreases COP
4. Compressor
5. Brine
6. Vortex refrigerator
7. Increases COP

Codes:

	A	B	C	D
(a)	1	6	5	3
(b)	4	2	3	7
(c)	1	2	5	3
(d)	4	6	3	7

Directions: The following items consists of two statements, one labelled as **Assertion** *A* and the other labelled as **Reason** *R*. You are to examine these two statements carefully and select the answers to these items using the codes given below:
(a) Both *A* and *R* are individually true and *R* is correct explanation of *A*
(b) Both *A* and *R* are individually true but *R* is not correct explanation of *A*
(c) *A* is true but *R* is false
(d) *A* is false but *R* is true

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Q.15 **Assertion (A):** Condensers of large refrigeration plants including central air-conditioning system are invariably water cooled.
Reason (R): Water has a higher specific heat.

Q.16 **Assertion (A):** Power input per TR of a refrigeration system increases with decrease in evaporator temperature.
Reason (R): COP of a refrigeration system decreases with decrease in evaporator temperature.

Numerical Data Type Questions

Q.17 The value of heat rejection ratios is 1.2 and the refrigeration effect is 2100 kJ/min then the heat rejected across condenser and COP is _____.

Q.18 For one-ton refrigeration capacity of the plant, if the heat rejection ratio of condenser is 1.4, the COP of the plant is _____.

Conventional Questions

Q.19 In a Bell Coleman refrigeration plant air enters the compressor at a pressure of 1 bar and a temperature of 10°C. It is then compressed to a pressure of 5 bar. Air is then cooled to 25°C in the cooler. Calculate
(i) Theoretical COP
(ii) RE/kg (Assume both compression and expansion to be isentropic having the valve of $\gamma = 1.4$, $c_p = 1.005$ kJ/kgK
(iii) $pV^{1.35} = C \rightarrow$ Compression
$pV^{1.3} = C \rightarrow$ Expansion
Then calculate
(a) COP (b) RE/kg

Q.20 The aircraft refrigeration system, air enters the compressor at a pressure of 0.1 MPa and a temperature of 4°C. It is then compressed to a pressure of 0.3 MPa with an isentropic efficiency of 72%. It is then cooled to a temperature of 55°C in the cooler, it is then further expanded to a pressure of 0.1 MPa within an isentropic efficiency of 78%. Assume air to be an ideal gas and the lower temperature air absorbs a cooling load of 3TR. Find:
(i) COP
(ii) Mass flow rate
(iii) Power consumption in kW

Try Yourself

T1. It is desired to make COP of a Carnot refrigeration system operating between –40 and +40°C is equal to 3.5 by changing the temperatures. The decrease in higher temperature is equal to the increase in lower temperature. Then determine the values of new temperatures in K.

[Ans.: $(T_H)_{New} = 307.125$ K, $(T_L)_{New} = 238.878$ K]

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6 Air-conditioning

Multiple Choice Questions

Q.1 If the percent humidity of air (30°C, total pressure 100 kPa) is 24% and the saturation pressure of water vapour at that temperature is 4 kPa, the percent relative humidity and the specific humidity of air are

(a) 24.75, 0.0062 (b) 25, 0.0035
(c) 24.75, 0.0055 (d) 18.2, 0.0035

Q.2 Dew point temperature of air at one atmospheric pressure (1.013 bar) is 18°C. The air dry bulb temperature is 30°C. The saturation pressure of water at 18°C and 30°C are 0.02062 bar and 0.04241 bar respectively. The specific heat of air and water vapour respectively are 1.005 and 1.88 kJ/kg and the latent heat of vaporization of water at 0°C is 2500 kJ/kg. The specific humidity (kg/kg of dry air) and enthalpy (kJ/kg of dry air) of this moist air respectively, are

(a) 0.01051, 52.64 (b) 0.01291, 63.15
(c) 0.01481, 76.60 (d) 0.01532, 81.40

Q.3 Water at 42°C is sprayed into steam of air at atmospheric pressure, dry bulb temperature of 40°C and a wet bulb temperature of 20°C. The air leaving the spray humidifier is not saturated. Which of the following statements is true?

(a) Air gets cooled and humidified
(b) Air gets heated and humidified
(c) Air gets heated and dehumidified
(d) Air gets cooled and dehumidified

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Q.4 Dew point temperature is the temperature at which condensation begins when the air is cooled at constant

(a) volume (b) entropy
(c) pressure (d) enthalpy

Q.5 Atmospheric air at a flow rate of 3 kg/s (on dry basis) enters a cooling and dehumidifying coil with an enthalpy of 85 kJ/kg of dry air and a humidity ratio of 19 grams per kg of dry air. The air leaves the coil with an enthalpy of 43 kJ/kg of dry air and a humidity ratio of 8 grams/kg of dry air. If the condensate water leaves the coil with an enthalpy of 67 kJ/kg, the required cooling capacity of the coil in kW, is

(a) 75.0 (b) 123.8
(c) 128.2 (d) 159.0

Q.6 When the relative humidity of humid air is 60%, water vapour in the air is the state of

(a) Saturated liquid
(b) Saturated vapour
(c) Superheated vapour
(d) Subcooled liquid

Q.7 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Specific humidity
B. Relative humidity
C. Specific volume of dry air

List-II

1. $\frac{P_v}{P_s}$ 2. $\frac{R_a P_v}{R_v (P - P_v)}$
3. $\frac{P_v (P - P_s)}{P_s (P - P_v)}$ 4. $\frac{R_a T}{(P - P_v)}$

Codes:

	A	B	C
(a)	1	2	3
(b)	2	3	4
(c)	2	1	4
(d)	4	3	2

Q.8 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Dry bulb temperature
B. Dew point temperature
C. Thermodynamic wet bulb temperature

List-II

1. Temperature of moist air
2. Temperature of air adiabatically saturated with water
3. Temperature indicated by a wet bulb thermometer
4. Saturation temperature corres ponding to partial pressure of water vapour in moist air

Codes:

	A	B	C
(a)	1	4	3
(b)	2	3	4
(c)	3	4	1
(d)	1	4	2

Q.9 Desert coolers are suitable for hot very dry out side conditions because

(a) water is recirculated in the spray
(b) heat is neither added nor removed from the water
(c) wet bulb depression ($t - t'$) is very large
(d) large quantity of air can be conditioned

Q.10 Consider the following statements

1. Low value of the by pass factor for an air conditioning equipment signifies higher performance of the equipment.
2. By pass factor for an air conditioning equipment signifies the fraction of ambient air mixed with the air to be conditioned.
3. By pass factor for an air conditioning equipment signifies the fraction of the air to be conditioned not coming in contact with the conditioning surface.

Which of these statements is/are correct?:

(a) 1 and 3 (b) 1 and 2
(c) 3 only (d) 2 only

Q.11 Two steams of moist air 1 and 2 mix together to give another stream of unsaturated air 3, Let m denote the rate of total mass flow of moist air, m_w denote the rate of mass flow of associated water vapour w denote the specific humidity and t the temperature of a stream. Then t_3 the temperature of stream 3 will be

(a) $\dfrac{(m_1 - m_{w1})\, w_1 t_1 + (m_2 - m_{w2}) w_2 t_2}{(m_3 - m_{w3}) w_3}$

(b) $\dfrac{(m_1 - m_{w1})\, t_1 + (m_2 - m_{w2}) t_2}{(m_3 - m_{w3})}$

(c) $\dfrac{w_1 t_1 + w_2 t_2}{w_2}$

(d) $\dfrac{m_1 w_1 t_1 + m_2 w_2 t_2}{m_3 w_3}$

Q.12 For air-conditioning the operation theatre in a hospital. The percentage of outside air in the air supplied is

(a) zero (b) 20
(c) 50 (d) 100

Q.13 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Steam spray in to air
B. Air passing over a coil carrying steam
C. Air passing over coil having temperature less than dew point
D. Air passing over a coil having temperature above the dew point but below the wbt

List-II

1. Sensible cooling
2. Cooling & dehumidification
3. Heating & humdification
4. Sensible heating

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	4	3	1	2
(c)	4	3	2	1
(d)	3	4	2	1

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Q.14 In the case of a cooling coil with Non-zero by pass factor; the apparatus dew point temperature lies at the intersection point of
(a) Room DB line with the saturation wave
(b) RSHF and GSHF lines
(c) RSHF and inlet conditions
(d) GSHF line with the saturation curve

Q.15 A sample of moist air is at a temperature T and relative humidity 50%. A part of the moisture is removed adiabatically by using an adsorbent. If the heat of adsorption is negligible the resulting air will have the same
(a) dry bulb temperature but a lower wet bulb temperature
(b) wet bulb temperature but a higher dry bulb temperature
(c) dry bulb temperature but a higher wet bulb temperature
(d) wet bulb temperature but a lower dry bulb temperature

Q.16 If a sample of moist air of 50% relative humidity at atmospheric pressure is isothermally compressed to a pressure of two atmospheres, then
(a) its relative humidity will reduce to 25%
(b) its relative humidity will remain unchanged
(c) the sample of air will become saturated
(d) saturation pressure will increase to twice the value

Q.17 The main process which takes place in desert cooler is
(a) sensible cooling
(b) dehumidification
(c) adiabatic saturation
(d) cooling and dehumidification

Q.18 Water in an insulated evaporative cooler evaporates at the rate of 0.003 kg/s. Air flow rate is 1 kg/s. What is the air temperature decrease if the specific heat of humid air is 1 kJ/kgK and latent heat of water is 2500 kJ/kg?
(a) 2.5°C
(b) 3.0°C
(c) 7.5°C
(d) 10°C

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Q.19 Consider the following statements pertaining to room sensible heat ratio (RSHR) line
1. It is the line drawn on psychometric chart through the room conditions
2. Its slope is the ratio is sensible cooling load to room latent heat load.
3. The supply air condition must lie on this line for satisfactory performance.

Which of the statements give above is/are correct?
(a) 1, 2 and 3
(b) 1 and 2
(c) 1 and 3
(d) 2 and 3

Common Data Questions Q.20 and Q.21

Moist air with a DBT of 40°C has a relative humidity of 50%. Atmospheric pressure is 1.01 bar. For water R_{H_2O} = 462 J/kJK, saturation pressure at 40°C is 7.38 kPa, and saturation pressure at 150°C is 4.758 bar.

Q.20 Specific humidity in grams/kg dry air is
(a) 23.6 (b) 37.9
(c) 52.2 (d) 61.0

Q.21 The moist air as stated above is compressed to 5.05 bar and its corresponding dry bulb temperature is 150°C. The relative humidity of this compressed air is
(a) 50% (b) 10%
(c) 3.9% (d) 0.8%

Q.22 Consider the following statements for refrigeration and air-conditioning:
1. In a refrigerating machine, the heat exchanger that absorbs heat is connected to a conditioned space.
2. A refrigerating cycle operating reversibly between two heat reservoirs has the highest coefficient of performance.
3. The lower the refrigeration required and the higher the temperature of heat rejection to the surroundings, the larger the power consumption.

Which of the above statements are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2017]

Q.23 Two air streams with mass flow rates of 36 kg/min and 14 kg/min with respective enthalpies of 36 kJ/kg da and 50 kJ/kg da are mixed. The enthalpy of the mixture is nearly

(a) 64 kJ/kg da (b) 55 kJ/kg da
(c) 46 kJ/kg da (d) 40 kJ/kg da

[ESE : 2017]

Q.24 Air at 30°C and 1 bar has a specific humidity of 0.016 kg/kg of dry air. By considering the saturation pressure of water vapour at 30°C as 4.246 kPa, the relative humidity of the air will be

(a) 66.1% (b) 60.2%
(c) 58.8% (d) 56.8%

[ESE : 2017]

Q.25 Consider the following statements in respect of an evaporative cooling process :

1. The wet-bulb temperature remains constant.
2. The dew-point temperature remains constant.
3. The enthalpy remains constant.

Which of the above statements are correct?

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2017]

Q.26 An air-conditioned room of volume 10 m^3 has infiltration of air equivalent to 3 air changes per hour. Density of air is 1.2 kg/m^3, specific heat C_P is 1 kJ/kgK and temperature difference between room and ambient air is 20 K. What is the sensible heat load due to infiltrated air?

(a) 60 kJ/hr (b) 12 kJ/hr
(c) 0.45 kW (d) 0.2 kW

[ESE : 2005]

Q.27 In an air-conditioning plant, air enters the cooling coil at 27°C. The coil surface temperature is –5°C. If the bypass factor of the unit is 0.4, the air will leave the coil at:

(a) 5.6°C (b) 7.8°C
(c) 9.2°C (d) 11.2°C [ESE : 2016]

Q.28 A stream of moist air at dry-bulb temperature of 40°C and dew-point temperature of 25°C passes through a water shower whose temperature is maintained at 20°C. The stream of air will undergo a process of

(a) sensible cooling
(b) evaporative cooling
(c) cooling and humidification
(d) cooling and dehumidification

[ESE : 2012]

Numerical Data Type Questions

Q.29 A stream of moist air (mass flow rate = 10.1 kg/s) with humidity ratio of 0.01 kg/kg dry air mixes with a second stream of superheated water vapour flowing at 0.1 kg/s. Assuming proper and uniform mixing with no condensation, the humidity ratio of the final stream (in kg/kg dry air) is _____.

[GATE : 2015]

Q.30 Moist air is treated as an ideal gas mixture of water vapor and dry air (molecular weight of air = 28.84 and molecular weight of water = 18). At a location, the total pressure is 100 kPa, the temperature is 30°C and the relative humidity is 55%. Given that the saturation pressure of water at 30°C is 4246 Pa, the mass of water vapor per kg of dry air is _____ grams.

[GATE : 2017]

Conventional Questions

Q.31 The DBT and WBT of atmospheric air are 30°C and 20°C respectively. The atmosphere pressure is 740 mm of Hg. then determine:

(i) Partial pressure of water vapour and dew point temperature
(ii) Specific humidity
(iii) Relative humidity
(iv) Vapour density

Saturated Temp. (°C)	Saturated Pressure (bar)
30	0.04242
20	0.02337
15	0.01679

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Q.32 In an air-conditioned space 50 kg/sec of fresh air at 45°C DBT and 30% relative humidity. The room air at 25°C DBT and 50% relative humidly is recirculated at 450 kg/sec. The mixed air is flows over a cooling coil which has an ADP of 12°C and bypass factor of 15%. Determine the condition at the outlet of cooling coil, room sensible heat, room latent heats, cooling load of the cooling coil and the condensate rate. The saturation pressure of water at the required temperatures are given below in table:

t(°C)	Sat. Press. (bar)
12	0.014016
25	0.03166
45	0.09584

Q.33 An AC plant supplies a total of 4500 m^3/min. of dry air which comprises 20% of fresh air at 40°C DBT and 27° WBT and 80% of recirculated air at 25°C DBT and 50% relative humidity. The air leaves the cooling coil at 13°C saturated. Calculate the

(i) Total cooling load

(ii) Room heat gain

Assume specific volume of air entering the cooling coil is (v) = 0.869 m^3/kg

Condition	DBT (°C)	WBT (°C)	RH(%)	w(gm/kg d.a.)	h(kJ/kg d.a.)
Outside	40	27	—	17.2	85
Inside	25	—	50	10.0	51
ADP	13	—	100	9.4	36.8

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Try Yourself

T1. The pressure, dry bulb temperature and relative humidity of air in a room are 1 bar, 30°C and 70%, respectively. If the saturated steam pressure at 30°C is 4.25 kPa. Find the specific humidity of the room air.

[Ans. 00.0191 kg water vapour/kg dry air]

T2. Atmospheric air at a dry bulb temperature of 38°C and wet bulb temperature of 18°C is humidified in an air-washer. Dry bulb temperature at the exit of the air washer is 24°C. Determine the percentage change in the wet bulb depression at the exit of the air washer?

[Ans. 70%]

T3. If for a cooling tower wet bulb depression at inlet is equal to sum of its range and approach then find the difference between temperature of water at inlet and dry bulb temperature of air at inlet?

[Ans. 0°C]

■■■■

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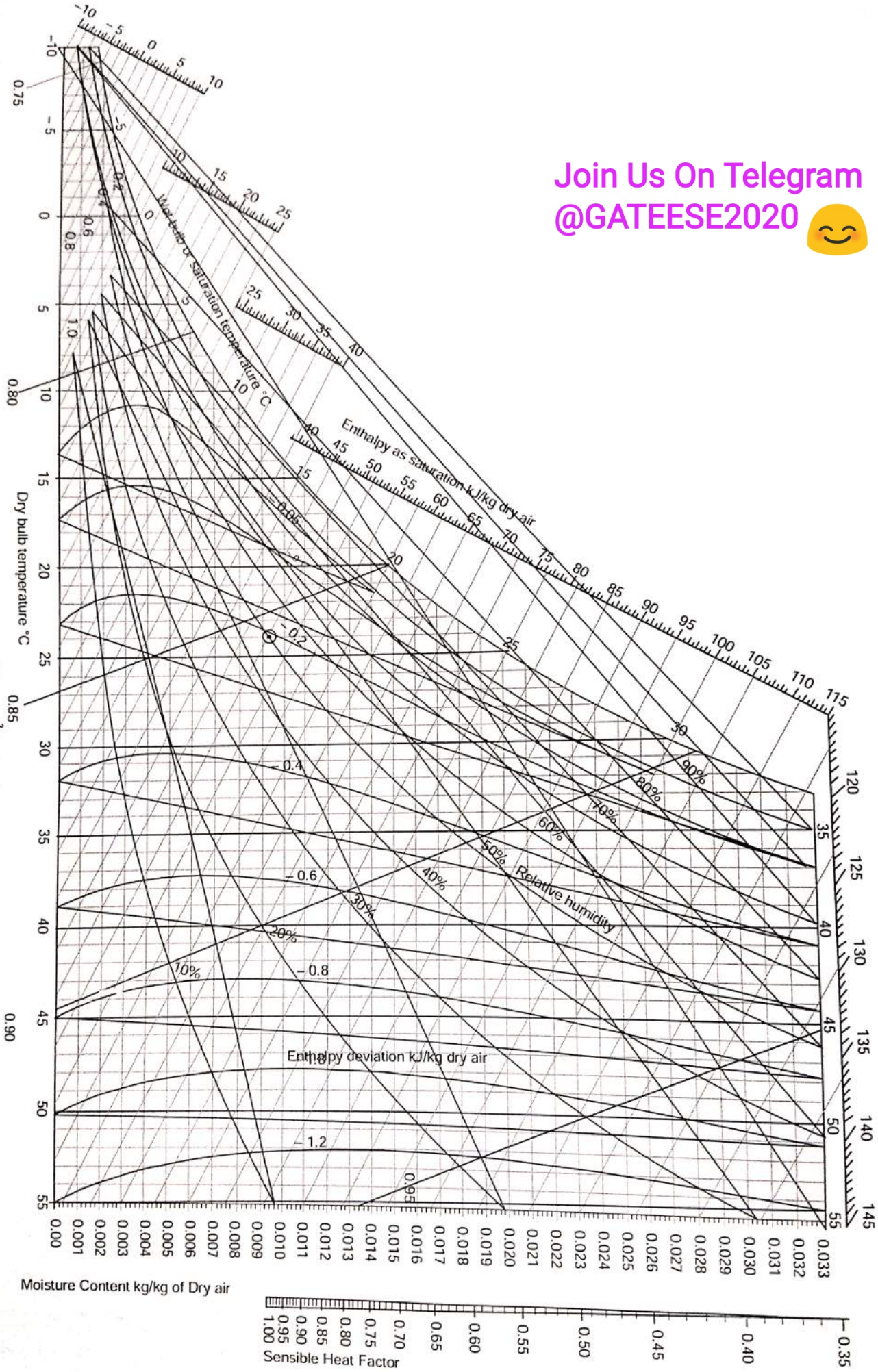
Dry bulb temperature °C
Wet bulb or saturation temperature °C
Enthalpy as saturation kJ/kg dry air
Relative humidity
Enthalpy deviation kJ/kg dry air
Volume m³ kg dry air
Moisture Content kg/kg of Dry air
Sensible Heat Factor